LEAF SHAPE & PIGMENTS FOR HEAT RESISTANCE IN A PEA ASSOCIATION MAPPING PANEL
Rosalind A. Bueckert, Yunfei Jiang, and Tom Warkentin, Dept. of Plant Sciences & Crop Development Center
rosalind.bueckert@usask.ca (306)-966-8826

RATIONAL

Canada is the leading global producer of grain pea (Pisum sativum L.), where this dryland crop is mostly grown on the semi-arid western prairies. Heat stress occurs in the field when pea crops are exposed to rapid or extreme air temperatures exceeding 28°C. To seek leaf traits that can improve heat resistance via canopy cooling for future cultivars, we measured a 94-member pea association mapping panel (PAM) consisting of cultivars selected for western, northern, and eastern Canada, and Australia. The PAM was measured in Arizona (2012) and Saskatchewan, Canada (2012, 2013, 2015).

Cultivars contain a range of:
- leaf type (normal, true leaf, semi-leafless),
- canopy color (bright green, blue-green, red-green, dark green),
- flower color (red, pink, white, cream),
- canopy habit (prostrate, vining, upright),
- determinacy (total and reproductive node number and lifecycle length).

Goals:
1. To select the best 20% yielding genotypes in growing seasons with high temperature (AZ 2012, SK 2015).
2. To determine if leaf canopy traits such as leaf shape and size, canopy habit, and leaf pigment content can be characterized with canopy cooling.

METHODS

94-member PAM collection grown in:
- AZ 2012, two seeding dates, single rows as plots, each with 2 replications.
- SK 2012, one seeding date, microplots, 2 or 3 of 6 replicates measured.
- Node number per plant, pod number per plant, reproductive nodes per plant.
- SK 2013, one seeding date in a normal to cool year, microplots, 2 replicates measured after flowering for:
  - leaf pigment content (anthocyanin, chlorophyll a and b, carotenoids),
  - SPAD readings (leaf canopy temperature),
  - node, pods and yield.

Pea has a compound leaf which was scanned with WinRhizo. Leaf samples were divided into petals and leaf surface: petals and tendrils for petioles, leaflets and stipules for leaf surface.

SK 2015, one seeding date but a HOT summer, microplots, 2 replicates measured after flowering for leaf pigment content, SPAD, IR canopy temperature, leaf scanning, and stem diameter (micrometer at expanded nodes 2-3 and nodes 3-4 from the top of the plant).

RESULTS

2013 data sets had less field measurements than 2015, as seen in the whole plant figure below. Out of 36 contrasts tested for each combination of whole plant, leaf pigment (leaf petiole plus tendril) measurement, many measurements were significantly sensitive to detect differences in genotypes.

Overall, leaf pigments were generally insensitive for detecting differences in genotypes and their variation in plant growth, yield and sensitivity to temperature stress.

The SPAD meter appears as effective, or better than laboratory analysis of pigments using spectrophotometric methods (Lichtenthaler equations, Food Science anthocyanin methods).

2015 was a hotter year, and anthocyanin content increased in leaves. Comparing leaf (leaf) to petioles, petiole material may be a greater source of pigments.

Leaf length (cumulative length of all leaf parts), area and average organ diameter were sensitive measurements, especially in the hot year of 2015.

The top 20% coolest genotypes from 2013 IR measurements were also significantly cooler in 2015, they were more green-blue, and had thicker stems.

Leaf size and shape characteristics:
- Making a canopy semileafless is a profound change, enabling a crop to remain upright and cool. Semileafless leaves have shorter cumulative length for stipules combined to entire leaves, along with smaller leaf surfaces. The shorter and smaller leaf, the greater the petiole length due to enhanced tendrils.
- Vining petioles had significantly more carotenoids than entire leaf petioles, along with smaller leaf surfaces. The shorter and smaller leaf, the greater the petiole length due to enhanced tendrils.

Pigment characteristics:
- Chlorophyll content was remarkably stable across genotypes and traits.
- Anthocyanin content was greater in petioles than leaves, anthocyanin content was associated with entire leaves, but not necessarily the red petiole trait.
- Vining petioles had more anthocyanin.
- Carotenoid content was stable in leaf, which tends to contain more than petioles. Semileafless petioles had significantly more carotenoids than entire petioles, making semileafless canopies the most.
- Carotenoid function in the xanthophyll stress pathway.
- Overall, for SPAD measurements were more sensitive to canopy trait differences than the spectrophotometric techniques we used.

CROP RESPONSE (mg cm-2)
- Leaf (leaflets, stipules), Petiole (petiole only).
- Leaf size and shape characteristics
- Chl A, B, Chl A+B, carotenoids.
- Leaf scanning for petiole, leaflet, stipule, tendril.
- Whole plant growth, yield, plus 2013 SPAD and IR.

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Rank Order Analysis by Quintile Group:

1. 2012 data divided into three sets:
- AZ 2012 seeding date 1: cool temperature,
- AZ 2012 seeding date 2: high temperature during reproduction (HOT),
- SK 2012 normal growing season in western Canada, cool temperature.

2. For each 2012 plant performance trait (node number, pod number, reproductive node number, plot yield, plus 2013 SPAD and IR), the 94 PAM entries were sorted from largest to smallest, and divided into quintiles (20% groups) for each of the three 2012 data sets.

Contrast statements were programmed to compare entries among quintiles using the 2012 plant performance traits.

The top quintile (80-100%) was compared to the next quintile (60-80%), the top quintile (60-80%) was compared to the middle quintile (40-60%), the top quintile (80-100%) was compared to the bottom quintile (0-20%).

Additional contrasts were programmed to compare leaf type (24 entire versus 70 semi-leafless, SL), canopy habit (20 prostrate/vining vs 74 upright), and flower color (11 red, pink or white vs 83 white).

5. ANOVA in PROC GLM in SAS (Version 9.3) was conducted on 2013 and 2015 data separately. The treatment structure within the 94 entries was tested via 36 contrasts on growth performance, SPAD, IR, leaf size, shape, stem diameter (2015), and leaf pigment contents.

Means for each measurement made in 2013 and 2015 were generated for each quintile in PROC MEANS after sorting data by all combinations of year, leaf type and quintile group.

3. ANOVA in PROC GLM in SAS (Version 9.3) was conducted on 2013 and 2015 data separately. The treatment structure within the 94 entries was tested via 36 contrasts on growth performance, SPAD, IR, leaf size, shape, stem diameter (2015), and leaf pigment contents.

Means for each measurement made in 2013 and 2015 were generated for each quintile in PROC MEANS after sorting data by all combinations of year, leaf part and quintile group.